Spring 2012

A Survey of the Orchid Diversity (Orchidaceae) in Sainte Luce, Petriky, and Mandena (Southeast Madagascar)

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Semester: Spring, 2012

Acknowledgments

I would especially like to thank David Rabehevitra, the QMM botanist who served as my advisor and helped me tremendously throughout this project. I would also like to thank Norlin Odoris, Marco Raherison, Roger Ramison, Give Sambo, and all others who helped me navigate and record information in the field. My host family deserves much appreciation for providing me with food, shelter, and support in between data collection. I thank my biological family at home in the United States for providing me with support, despite being a continent and an ocean away. I thank Plato Wilson, the generous donor who provided me with funding for my education and without whom this experience would not have been possible. Thanks to the SIT Madagascar staff for helping me set up this project and to Kathryn Theiss for suggesting this particular study site. Last but not least, I thank all of the professors, teachers, and mentors I've had who've helped me learn to think critically – of these, I especially thank Kathleen Pryer, Carl Rothfels, and Michael Windham.

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Abstract

This study examines the orchid diversity within three littoral forest sites in Southeast Madagascar. The sites, Sainte Luce, Petriky, and Mandena, are owned and managed by QIT Madagascar Minerals (QMM), an ilmenite mining organization jointly owned by Rio Tinto and the Malagasy government. The littoral forest is a habitat type dwindling in surface area; as such, it is a high conservation priority, and a portion of each of these three sites will be conserved by QMM. This study produces a list of orchid species present in the three zones, a list of host tree species on which epiphytic orchid species are found in the zones, and a comparison of species frequencies and richness of genera between zones. This study finds a total of 39 orchid species in the three zones, with the highest amount of overall orchid diversity in Sainte Luce and the highest amount of terrestrial orchid diversity in Petriky. When the species list generated by this study is combined with that from previous studies, a total of 45 orchid species and 18 genera are known within the three zones. This study adds to the knowledge of orchid biodiversity in the three zones with the goal of better enabling QMM to execute its conservation efforts within them.

Introduction

Orchidaceae is a family of vascular plants consisting of almost 25,000 species (Gravendeel et al., 2004). As such, it is the largest flowering plant family in the world (Huynh et al., 2009). Species of this family are typically famed for their tight and often fascinating relationships with pollinators. Some orchid flowers take on the shape of an insect, provoking a species of pollinator to attack it or try and copulate with it. Other flowers attract certain pollinators by emitting a specific odor or by offering a delicious nectar. An orchid species and its pollinator are often so closely evolved that the two depend on each other for survival (Orlean, 1998). Orchids are notable for other symbioses, too. All orchids, for example, grow with the aid of mycorrhizal fungi (fungi which increase a plant root's ability to take in water and nutrients) during the seedling stage, and many orchids continue to interact with these fungi during adulthood (Rasmussen, 2002). Furthermore, orchids frequently depend on other plants for space to live; more than 70% of all orchid species are epiphytic (Gravendeel et al., 2004).

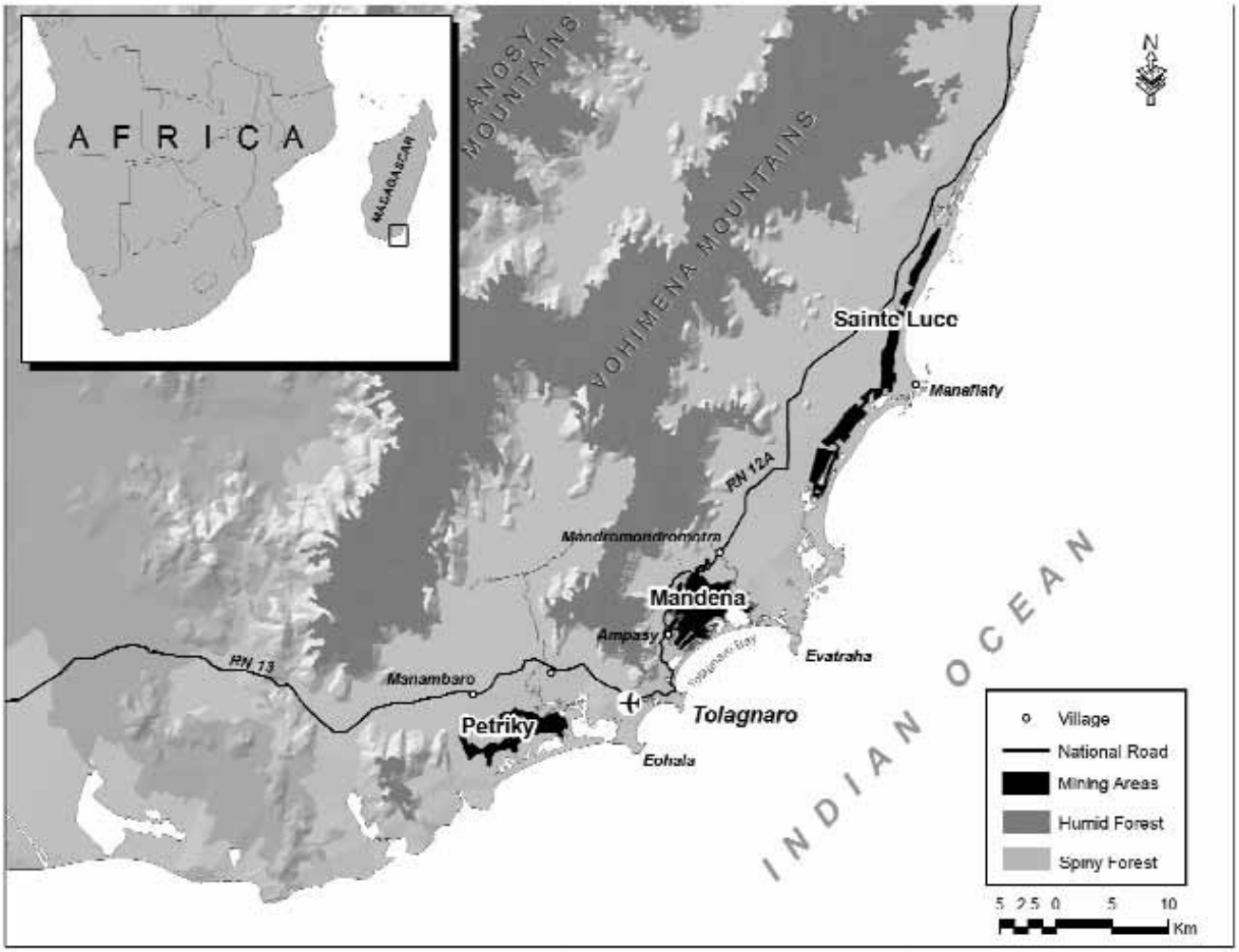
Madagascar is home to as many as 1,000 orchid species, of which almost 90% are endemic to the island (Cribb and Hermans, 2009). At the same time, the habitats in which these species live are dwindling. Less than 10% of Madagascar's surface area remains covered by natural vegetation today (Cribb and Hermans, 2009). The habitat loss faced in Madagascar and the resulting erosion are so extreme, in fact, that the country has been nicknamed “The Red Island” (Kouwenhouven, 1996). This makes the ability to study the health of its natural communities vital for conservation efforts. Because orchids interact with at least two or three other species (including a pollinator species and a mycorrhizal fungi species) during their life cycle, they can serve as a window through which to study broader natural communities. The capacity of orchids to reveal the health of broader natural communities combined with the threats faced by Madagascar's natural communities make the study of Madagascar's rich orchid diversity a vital pursuit.

The littoral forest is a natural community type in Madagascar that is especially at risk and, at the same time, especially high in floristic biodiversity. At its original size, the littoral forest covered only 1% of Madagascar's surface area (Rabehevitra, 2007), and only 10% of it, at most, remains today (Missouri Botanical Gardens, 2012). What little remains of this habitat is at risk due to the fragility of its unconsolidated sandy soils combined with its proximity to human settlement. Because of its proximity to human settlement, it's threatened by slash and burn cultivation practices and "woodcutting for construction and charcoal." Meanwhile, despite its small size, the littoral forest is home to 13% of Madagascar's native flora, and 25% of the plant species found within it are endemic to this particular forest type (Rabehevitra, 2007). This makes the littoral forest habitat a high conservation priority and the understanding of its biodiversity and overall health, as revealed by indicator species like those within Orchidaceae, essential.

This study examines the orchid diversity found in three Southeastern littoral forest sites: Sainte Luce, Petriky, and Mandena (see Fig. 1). Each of these sites, which are centered around Fort Dauphin, consists of a current or future ilmenite mining zone owned by QIT Madagascar Minerals (QMM), a mining organization jointly owned by Rio Tinto and the Malagasy government. In each site, a zone of conservation will be established and exempt from ilmenite extraction. As such, these zones will form part of the very small amount of littoral forest remaining in Madagascar. The littoral forests around Fort Dauphin have declined in surface area by 56% between 1950 and 2008 (Vincelette, Théberge, et al., 2007). The critical condition of this habitat type around Fort Dauphin makes the conservation by QMM of forest area in these three zones extremely important. This study aims to increase the understanding of the orchid diversity within these zones in order to increase QMM's capacity to monitor and conserve the littoral forests within them.

The concrete results of this study will be a list of species found in each of the three mining zones and comparisons of species frequencies and richness of genera between zones. Previous work

Figure 1. Map showing Sainte Luce, Petriky, and Mandena and their location in Southeast Madagascar. Image from Vincelette, Dean, et al., 2007.



on the orchid flora of these mining zones is minimal. In 2007, QMM executed a floristic survey of the vascular plant species found in the mining zones and broader littoral forests around Fort Dauphin; this survey identified 18 different orchid species, six of which are restricted to the littoral forests of the QMM and Fort Dauphin area (Rabenantoandro et al., 2007). Beyond this report, little is known about the orchid flora of the area. Additionally, the region's orchid flora is not fully understood systematically; many species of the genus *Bulbophyllum*, for example, have not yet been described and named (personal communication with David Rabehevitra). This study aims to deepen the as-of-now

weak understanding of orchid diversity in this forest type and especially in the three QMM mining zones in order to improve QMM's ability to monitor and conserve three important littoral forest sites.

Methods

To execute this study, a minimum of three days were spent in each QMM mining zone. In each zone, forest surface was surveyed for orchids. Anytime an orchid species not already seen was found, the following information was collected: GPS location, species name, number of individuals, number of colonies (if applicable), host tree species (if applicable), and other habitat preferences. If a species could not be immediately identified, either a photo was taken or a specimen was collected to facilitate later identification. When a species was found at a higher concentration than previously seen during the study, a square plot of five meters by five meters was established. In the plot, the number of individuals (and colonies, if applicable) and other information listed above were noted for this species as well as for all other species found in the plot.

After this information was collected, species that couldn't be immediately identified on site were identified using the photos taken or the specimens collected. These materials were juxtaposed with photos and descriptions found in Biotype's *Les Orchidées de Madagascar* (Bosser and Lecoufle, 2011) and Kew's *Field Guide to the Orchids of Madagascar* (Cribb and Hermans, 2009). In this way, nearly all orchid species seen during this study were identified. When a certain species couldn't be identified down to species level, it was described as *Genus* plus *sp* (for example, *Bulbophyllum sp*). When a certain species could be identified down to species level but there was any reason for doubt about the correctness of this identification, the species epithet was preceded with "*cf*" (for example, *Oeceoclades cf spathulifera*).

The result of these processes was a list of species found in each QMM mining zone along with a list of the maximum number of individuals within a five by five meter plot for each. The values for

maximum number of individuals in a five by five meter plot were simplified to one number by dividing the number of individuals in the plot by 25 meters squared. This generated a list of numbers of individuals per meters squared for each species in each zone. This number for a given species will be referred to as its maximum density within a five by five meter plot.

Graphical comparisons were performed using these maximum density values and other information collected using spreadsheet functions in LibreOffice (Version 3.4, 2012).

Results

This study found a total of 39 orchid species in the three QMM mining zones, with 23 species in Sainte Luce, 14 in Petriky, and 19 in Mandena (see Table 1). Most of these species were identified with certainty down to species level, but those that weren't are described morphologically in Appendix 1.

The three zones differ in number of orchid species, the percentage of epiphytic versus terrestrial species, the maximum densities of individual species, and the number of species in certain genera. Going by sheer number of species, this study indicates that Sainte Luce, with 23 species, is the richest of the three sites in terms of orchid diversity, followed by Mandena, with 19 species; Petriky, with 14 species, has the lowest amount of orchid diversity of the three zones. At the same time, however, Petriky is the zone with the greatest number of terrestrial species. It contains more than twice as many terrestrial orchid species as Sainte Luce, and more than 50% of its orchid species are terrestrial (see Fig. 2). Furthermore, the zones differ in the maximum densities at which certain species are found; for example, *Angraecum calceolus* and *A. sesquipedale* had the highest maximum densities within plots of 25 meters squared in Petriky, and *Cynorkis elata*, *C. fastigiata,* and most species of *Bulbophyllum* had their highest maximum densities in Sainte Luce (see Fig. 3). To see the maximum density values of all species found during this study, see Appendix 2. Lastly, certain genera had more species in certain zones than in others (see Fig. 4). This is especially true for the genera *Angraecum, Bulbophyllum,*

Table 1. Orchid species found in each zone during this study. STL = Sainte Luce; PTK = Petriky; MDN = Mandena.

Species	STL	PTK	MDN
Angraecum calceolus Thouars	X	X	X
Angraecum cf rhizomaniacum Schltr.	X		
Angraecum crassum Thouars	X		
Angraecum eburneum var. superbum (Thouars) H.Perrier		X	
Angraecum eburneum var. xerophilum H.Perrier		X	
Angraecum filicornu Thouars	X		
Angraecum sesquipedale Thouars	X	X	
Bulbophyllum cf cirrhoglossum H.Perrier	X	X	X
Bulbophyllum cf humblotii Rolfe	X		X
Bulbophyllum cf multiflorum Ridl.	X		X
Bulbophyllum cf vestitum var. meridionale Bosser	X		
Bulbophyllum elliotii Rolfe	X		
Bulbophyllum longiflorum Thouars			X
Bulbophyllum sp1	X		
Bulbophyllum sp2		X	
Bulbophyllum sp3		X	
Bulbophyllum sp4			X
Cymbidiella falcigera (Rchb.f.) Garay	X		X
Cymbidiella flabellata (Thouars) Lindl.			X
Cynorkis elata Rolfe	X		X
Cynorkis fastigiata Thouars	X		X
Disperis tripetaloides (Thou.) Lindl.			X
Eulophia beravensis Rchb.f.		X	
Eulophia macra Ridl.		X	X
Eulophia sp1		X	
Eulophia sp2			X
Grammangis ellisii (Lindl.) Rchb.f.	X		
Graphorkis concolor (Lindl.) Kuntze *var. alphabetica* F.N.Rasm.	X		X
Jumellea cf rigida Schltr.	X		
Jumellea stenoglossa H.Perrier	X		
Microcoelia aphylla (Thouars) Summerh.			X
Oeceoclades cf calcarata (Schltr.) Garay & P.Taylor		X	
Oeceoclades cf spathulifera (H.Perrier) Garay & P.Taylor		X	

Table 1 continued.

Species	STL	PTK	MDN
Oeceoclades longibracteata Bosser & Morat		X	
Oeceoclades maculata (Lindl.) Lindl.		X	
Oeceoclades pulchra (Thouars) P.J.Cribb & M.A.Clem.	X		X
Oeonia volucris (Thouars) Spreng.	X		X
Oeoniella polystachys (Thouars) Schltr.	X	X	X
Polystachya concreta (Jacq.) Garay & H.R.Sweet	X		X
Vanilla planifolia Andrews	X		

Eulophia, *Jumellea,* and *Oeceoclades*. The genera *Angraecum, Bulbophyllum,* and *Jumellea* had the highest number of species in Sainte Luce, while *Eulophia* and *Oeceoclades* had the highest number of species in Petriky. There were no genera strikingly more rich in Mandena than in the other zones.

For epiphytic orchid species, host tree species were noted in the field. A complete list of which orchid species had which hosts can be found in Appendix 3. Five tree species were found to be hosts for an especially high number of orchid species; these are *Diospyros sp, Eugenia sp, Intsia bijuga*, *Sarcolaena multiflora*, and *Uapaca sp* (see Fig. 5). Each of these five species was observed as a host for six or more different epiphytic orchid species.

The phenologies of species observed in this study can be found in Appendix 4.

Figure 2. Total number of orchid species found in each mining zone, and frequency of epiphytic versus terrestrial growth habits in each zone. STL = Sainte Luce; PTK = Petriky; MDN = Mandena.

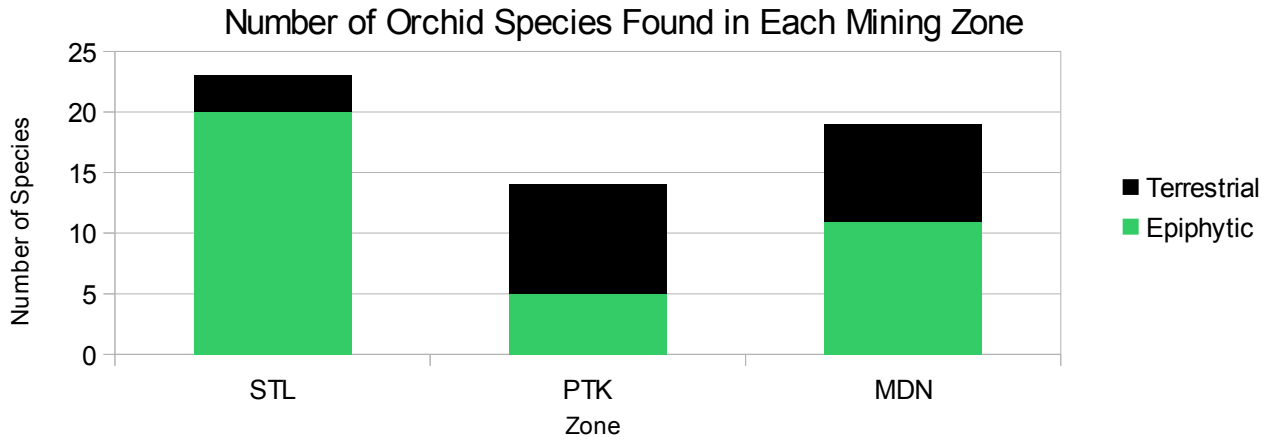


Figure 3. The maximum densities within a five by five meter plot of species found in more than one zone. For species marked with an asterisk, the density unit is number of colonies per meter squared. STL = Sainte Luce; PTK = Petriky; MDN = Mandena.

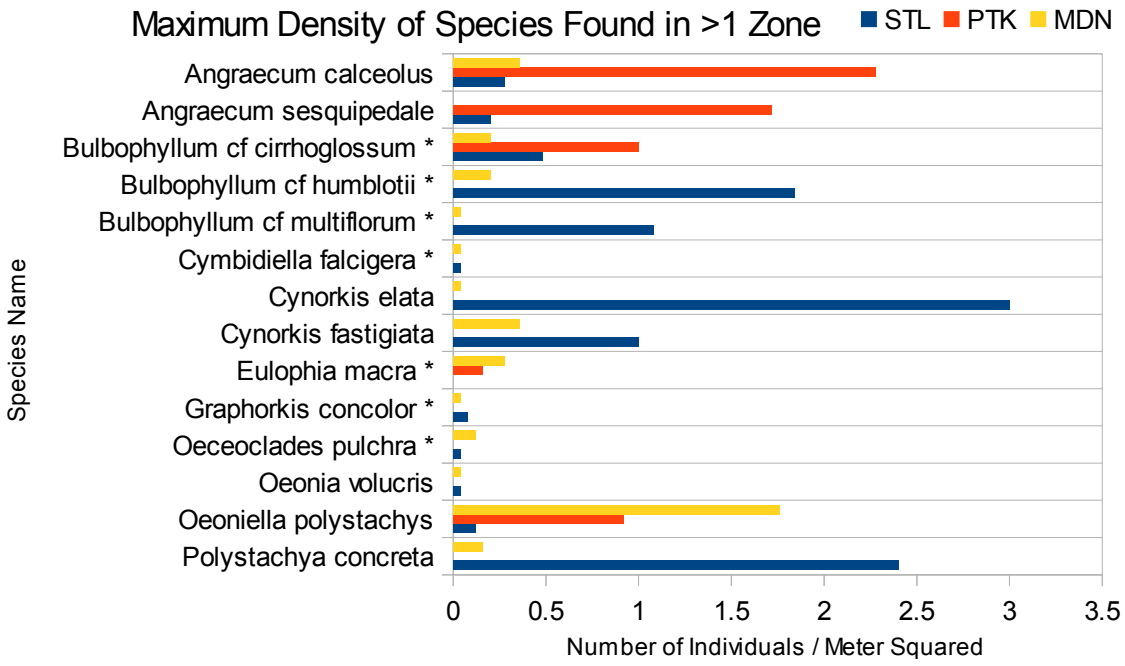


Figure 4. The number of species found in each genus in each zone. STL = Sainte Luce; PTK = Petriky; MDN = Mandena.

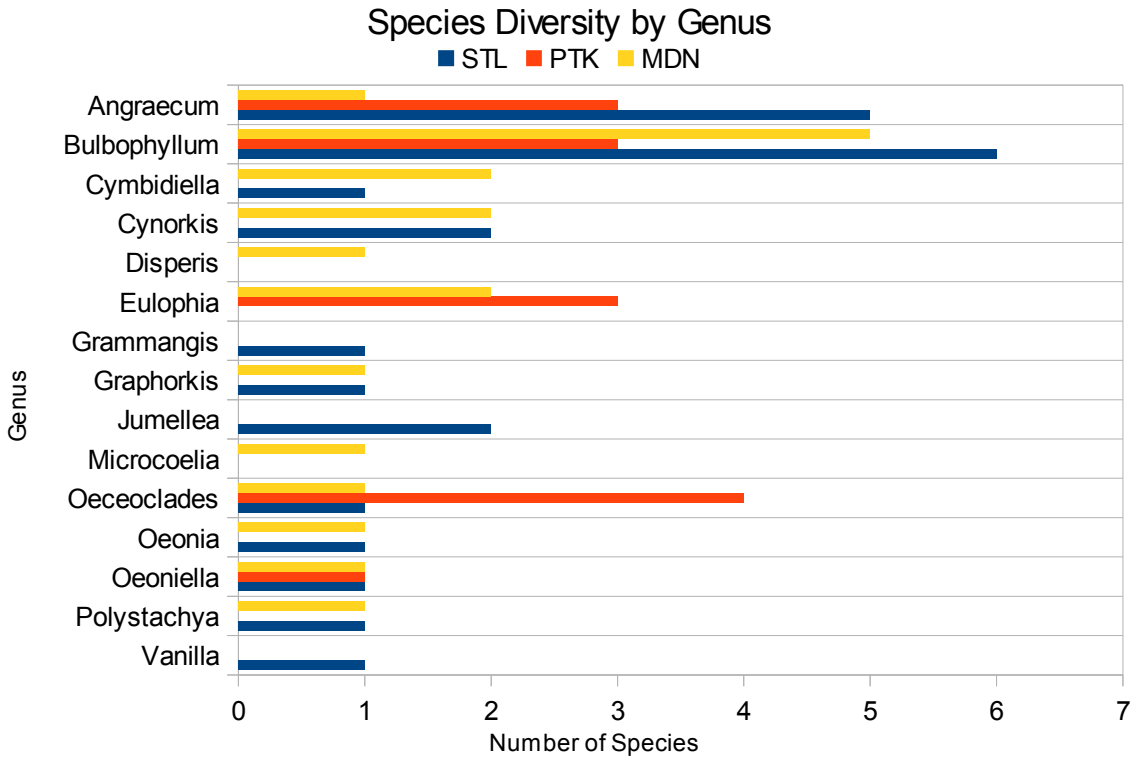
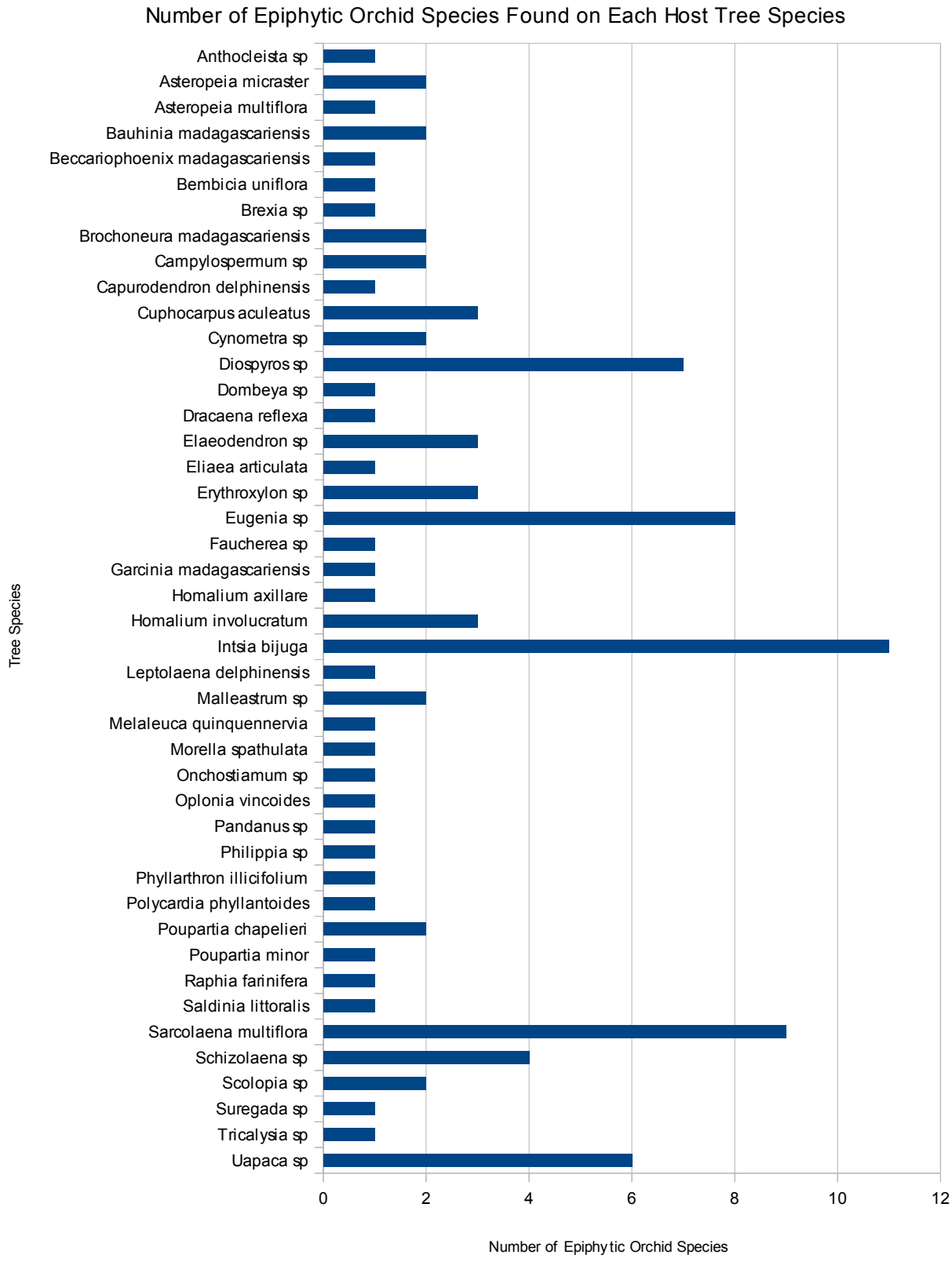


Figure 5. Host tree species and the number of epiphytic orchid species found on each.



Discussion

In all, this study found 39 orchid species within the QMM mining zones. This is a huge increase from 18 species, which is what Rabenantoandro et al. recorded in 2007. The species list generated by this study is combined with that of Rabenantoandro et al., 2007 in Table 2. Some orchid species, like *Aerangis citrata* and *Aeranthes grandiflora*, were found in 2007 but not in this study; when these are added to the species count generated by this study, there is a grand total of 45 orchid species and 18 orchid genera known in the mining zones. These results newly place Orchidaceae within the list of the

Table 2. Orchid species found in this study (2012) juxtaposed with those found by Rabenantoandro et al. in 2007. Species found in this study that were not found in a certain zone in 2007 are marked with an asterisk. STL = Sainte Luce; PTK = Petriky; MDN = Mandena.

Species	STL 2007	STL 2012	PTK 2007	PTK 2012	MDN 2007	MDN 2012
Aerangis citrata (Thouars) Schltr.	X					
Aerangis fuscata (Rchb.f.) Schltr.	X				X	
Aeranthes grandiflora Lindl.			X		X	
Angraecum calceolus	X	X		X*		X*
Angraecum cf rhizomaniacum		X*				
Angraecum crassum		X*				
Angraecum eburneum	X			X*	X	
Angraecum filicornu		X*				
Angraecum sesquipedale	X	X		X*	X	
Bulbophyllum cf cirrhoglossum		X*		X*		X*
Bulbophyllum cf humblotii		X*				X*
Bulbophyllum cf multiflorum		X*				X*
Bulbophyllum cf vestitum var. meridionale		X*				
Bulbophyllum elliotii	X	X				
Bulbophyllum longiflorum						X*
Bulbophyllum matitanense H.Perrier					X	
Bulbophyllum sp1		X*				
Bulbophyllum sp2				X*		
Bulbophyllum sp3				X*		
Bulbophyllum sp4						X*
Cymbidiella falcigera		X*			X	X

Table 2 continued.

Species	STL 2007	STL 2012	PTK 2007	PTK 2012	MDN 2007	MDN 2012
Cymbidiella flabellata						X*
Cynorkis elata	X	X			X	X
Cynorkis fastigiata	X	X				X*
Disperis tripetaloides						X*
Eulophia beravensis				X*		
Eulophia filifolia Bosser & Morat			X			
Eulophia macra				X*		X*
Eulophia sp1				X*		
Eulophia sp2						X*
Grammangis ellisii		X*				
Graphorkis concolor var. alphabetica		X*				X*
Jumellea cf rigida		X*				
Jumellea stenoglossa		X*				
Microcoelia aphylla					X	X
Oeceoclades cf calcarata				X*		
Oeceoclades cf spathulifera				X*		
Oeceoclades longibracteata	X		X	X		
Oeceoclades maculata				X*		
Oeceoclades pulchra		X*				X*
Oeonia volucris		X*			X	X
Oeoniella polystachys		X*		X*	X	X
Paralophia palmicola (H.Perrier) P.J.Cribb & Hermans					X	
Polystachya concreta		X*			X	X
Vanilla planifolia		X*				

five most highly represented vascular plant families found in the three mining zones, along with Euphorbiaceae, Rubiaceae, Fabaceae, and Apocynaceae. These families are ranked in terms of number of species in Table 3.

The majority of the orchid species present overall in the mining zones are epiphytic. This is true in Sainte Luce and Mandena. In Petriky, however, the majority of the orchid species present are terrestrial. Petriky is the zone both with the greatest number of terrestrial orchid species and with the

Table 3. The five most highly represented vascular plant families found in the QMM zones. Modified from Rabenantoandro et al., 2007.

Family	Number of Species	Number of Genera
Euphorbiaceae	52	18
Orchidaceae	45	18
Rubiaceae	32	23
Fabaceae	27	21
Apocynaceae	19	11

highest proportion of its orchid flora composed of terrestrial species (Fig. 2). This suggests that there are broader differences to be found between zones. Indeed, the climate of Petriky is drier than those of Sainte Luce and Mandena, and its canopy is lower and more open (Rabenantoandro et al., 2007). Furthermore, its leaf litter layer is thinner than those of the other zones (personal communication with David Rabehevitra). This may be an explanation for its large quantity of terrestrial species. A more open canopy and a thinner leaf litter layer would provide the opportunity for terrestrial orchid species to claim space on the forest floor, whereas the closed canopies and thick leaf litter layers in Sainte Luce and Mandena may render epiphytism the better option.

Beyond these obvious differences in forest structure between zones, there are other possible differences that may further explain the differing frequencies of terrestrial versus epiphytic orchid species. For example, it's possible that a greater frequency of terrestrial species in Petriky is related to the presence of certain mycorrhizal fungi that may be absent from the other zones. Likewise, the absence of certain mycorrhizal fungi on potential host trees may relate to a lower number of epiphytic orchid species. Another important factor influencing the terrestrial versus epiphytic composition of an orchid flora may be which tree species dominate in a given zone or what the average size and age class of the zone's trees are. These are speculations that should be investigated in future studies.

Certain orchid genera were found to be remarkably richer in some zones for others (Fig. 4). Not surprisingly, the two genera richest (with the greatest number of species) in Petriky are *Eulophia* and

Oeceoclades, both of which are terrestrial. *Angraecum*, *Bulbophyllum*, and *Jumellea* are richest in Sainte Luce. The *Bulbophyllum* and *Jumellea* species found in this study are exclusively epiphytic, and the *Angraecum* species found in this study are mostly epiphytic; the exceptions are *Angraecum crassum*, *A. eburneum*, and *A. sesquipedale*, which are capable of both epiphytic and terrestrial growth habits. Sainte Luce, where these epiphytic genera are richest, is the zone with the greatest number of epiphytic species and the greatest proportion of its orchid flora composed of epiphytic species (Fig. 2). It contains more than twice as many epiphytic species as Petriky and almost twice as many epiphytic species as Mandena. Mandena seems to be transitional in terms of orchid diversity; no genera were overwhelmingly richest in this zone, and it is intermediate between zones in terms of its composition of terrestrial versus epiphytic species.

The Genus *Bulbophyllum*

The genus *Bulbophyllum*, of which the systematics is poorly understood, was found to have a high diversity in the mining zones, with three species observed in Petriky, five in Mandena, and six in Sainte Luce (Fig. 4). A total of ten species was found in all (Table 1). Most of these were impossible to identify with certainty down to species level due to the following factors: the absence of a *Bulbophyllum* flora with keys using only vegetative characteristics and the fact that some species observed probably haven't yet been named. For some of the species found in this study, either a scientific name does not yet exist, or the species is not found in a key enabling identification without floristic characteristics. As almost none of the *Bulbophyllum* species found in this study were in flower at the time (mid-April, 2012), identification was difficult or impossible within this genus. The species of *Bulbophyllum* that were found in flower or fruit are indicated in Appendix 4.

The *Bulbophyllum cf cirrhoglossum* found in this study merits further attention. A description of individuals identified by this study as *B. cf cirrhoglossum* is given in Appendix 1. Although all

individuals identified as this species match the description given and have an overall similar appearance, there were differences among them suggesting that perhaps they do not all belong to the same species. For example, individuals identified as this species varied in number of flower rows present on the inflorescence; for some individuals, there were distinctly three rows, but for others, there were four. Additionally, there were variations in pseudobulb form; although all individuals had slightly flattened pseudobulbs, some had pseudobulbs that were subtly angled whereas others had pseudobulbs that were perfectly smooth. It's extremely probable that some plants identified by this study as *B. cf cirrhoglossum* belong to separate species.

Host Trees

This study noted a total of 44 different host tree species for the epiphytic orchids of the three zones (Fig. 5). The most notable of these host tree species are *Diospyros sp, Eugenia sp, Intsia bijuga*, *Sarcolaena multiflora*, and *Uapaca sp*, each of which was found as a host for six or more different epiphytic species. *Intsia bijuga* was found as a host for 11 different epiphytic species. The host species noted in this study varied greatly in terms of age, size, and bark texture, but overall, it was more common to see rough-barked species, like *Sarcolaena multiflora*, and older trees with large diameters serving as hosts. Lastly, most host tree species on which orchids were observed in this study are endemic to Madagascar, but a few, such as *Melaleuca quinquennervia*, are non-native. The identity of host tree species must be considered in future epiphyte surveys, conservation efforts, and reforestation efforts. These species are important because they do not exist alone; their presence opens up habitat for other species, including the epiphytic orchid species found in this study.

Conclusion

This study shines light on the poorly understood orchid flora of Sainte Luce, Petriky, and Mandena. Its results compiled with those of Rabenantoandro et al. from 2007 indicate that there are at least 45 orchid species and 18 genera found within the three QMM mining zones. Furthermore, it reveals differences between zones in terms of frequency of individual orchid species, proportion of terrestrial versus epiphytic species, and richness of particular genera. Also, it presents a list of host tree species. The unique orchid diversity observed in each zone combined with the fact that these zones form a part of the very little remaining littoral forest habitat in Madagascar are a reminder of the importance of their conservation. This increased understanding of orchid diversity within the three zones and of differences in orchid diversity between them can be used by QMM as they carry out future surveys and conservation measures within these remaining pieces of littoral forest.

Several questions meriting further pursuit arise from this study. First of all, it is possible and even highly likely that there are orchid species present in the three mining zones that remain unreported. Orchid surveys should be conducted at different times of the year in an effort to catch any as-of-now overlooked species that may be in flower during other seasons. Furthermore, future studies on *Bulbophyllum* should be done so that the exact number of species within this genus can be confirmed and so that any unnamed species can be named and described. Lastly, factors that relate to the proportion of terrestrial versus epiphytic species, such as mycorrhizal fungi and which tree species dominate in which zone, should be studied so that broader differences between zones can become better understood. As more is learned about the biodiversity of these three littoral forest zones, organizations like QMM that are involved in littoral forest conservation will become better able to protect the remaining fragments of this highly endangered habitat type.

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Appendix 1. Descriptions of species not identified with certainty down to species level.

Angraecum cf rhizomaniacum
leaves up to 6 cm long and 0.7 cm wide, lime green to deep green; 0.2 - 0.5 cm between leaves; stem zig-zagged, 0.2 cm wide, light green; roots light green, 0.1 cm wide, creeping down host tree; tends to grow on small branches or twigs; flower transparent yellow-green, up to 0.7 cm wide, 0.3 cm tall, 0.3 cm long; spur up to 0.9 cm long

Bulbophyllum cf cirrhoglossum
2 leaves/pseudobulb; pseudobulbs slightly flattened, up to 2.4 x 2 cm, up to 0.9 cm thick, light lime green; leaves up to 4.2 x 1.7 cm, light jade green; inflorescence up to 22 cm long, arcs downward; fruits up to 0.9 x 0.6 cm

Bulbophyllum cf humblotii
1 leaf/pseudobulb; pseudobulbs egg-shaped, up to 0.8 x 0.6 cm, light green, spaced 0.6 – 2.7 cm apart on rhizome; leaves light green, up to 3.1 cm long and 1.1 cm wide, up to 0.2 cm thick; flowers 0.5 cm long, petals and sepals transparent white, rostellum yellow; up to 11 flowers per inflorescence

Bulbophyllum cf multiflorum
1 leaf/pseudobulb; pseudobulbs 4-angled, up to 1.3 x 1 cm, up to 2 cm tall, light lime green, spaced up to 1 cm apart on rhizome; leaves up to 9.5 x 2.1 cm, 0.1 – 0.2 cm thick, light jade green, tinted purple on abaxial surface; entire leaf tinted purple when young; inflorescence up to 43 cm long; fruits up to 1.5 cm x 0.7 cm

Bulbophyllum cf vestitum var. meridionale
2 leaves/pseudobulb; pseudobulbs roughly 3-angled, up to 3.8 long x 3.2 wide x 2.4 cm thick, light lime green, spaced up to 3 cm apart on rhizome; leaves up to 20 x 2.9 cm, less than 0.1 cm thick, lime green, lighter in color on backside than frontside, oblanceolate, leaf blade gradually shrinking into a petiole about 0.3 cm thick; inflorescence up to 25 cm long; fruits up to 2.4 long, up to 1.7 cm in diameter, many-angled, dull lime green

Bulbophyllum sp1
2 leaves/pseudobulb; pseudobulbs flat, sometimes curving over other pseudobulbs, up to 1.6 cm x 1.8 cm, lime green; leaves up to 4.2 cm x 1.4 cm, jade green; inflorescences up to 27 cm long

Bulbophyllum sp2
2 leaves/pseudobulb; pseudobulbs flattened, round, up to 1.5 cm x 1.5 cm, lighter green than leaves; leaves 2 cm long x 1 cm wide, jutting outward instead of sitting flat against tree bark; inflorescence 8 – 9 cm long, drooping down downward; flowers in 3 rows; bracts up to 0.5 cm long

Bulbophyllum sp3
2 leaves/pseudobulb; pseudobulbs up to 1.6 cm wide x 2.6 cm long, flattened, becoming less wide toward apex, arc upward slightly toward apex, lighter green than leaves; leaves up to 4.5 cm long x 1 cm wide, not flattened against bark; inflorescence 8 – 9 cm long, bracts present; several 1 mm thick green-white roots coming from each pseudobulb

Bulbophyllum sp4
2 leaves/pseudobulb; pseudobulbs up to 5 cm long; leaves up to 12 cm long x 4 cm wide; inflorescence about 25 cm long, drooping downward, thickened in the lower 1/3rd where flowers are produced, bracts present

Eulophia sp1
4 – 7 leaves/pseudobulb; pseudobulbs cylindrical, stem-like, white, 3 – 5 cm tall x 0.75 cm wide; leaves linear, veins easily felt, folded at center vein, grass-like, 10 – 45 cm long x 0.5 cm wide; inflorescence 52 cm tall, diameter 0.2 cm

Eulophia sp2
2 leaves/pseudobulb; pseudobulbs underground, green, covered by sheaths, spaced about 1.5 cm apart on rhizome; leaves up to 28 cm long x 0.9 cm wide, thick and leathery, margins microscopically serrate, apex acute, petiolate at base; roots white

Jumeallea cf rigida
leaves v-shaped in cross section, lime green to jade green, asymmetrically lobed at apex, up to 9 cm long x 1.3 cm wide, spaced 0 cm apart; stem is a staircase of old leaf scars; roots up to 0.4 cm thick

Oeceoclades cf calcarata
3 leaves/pseudobulb; pseudobulbs up to 8 – 12 cm tall x 5 cm wide, green, sheathed at base, 5 – 8 angled, clustered closely together; leaves up to 45 cm long x 2 – 3 cm wide, thick, leathery, veins not detectable, folded at center vein; inflorescence up to 1.5 m tall, diameter 1.5 cm; fruits 6 cm long with a diameter of 1.5 cm, bearing 6 narrow ridges

Oeceoclades cf spathulifera
pseudobulb underground; leaves about 15 cm long x 2 cm wide, light green, mottled with dark green; inflorescence about 75 m tall; fruits with ridges about 3 – 5 mm wide, purple-brown

Appendix 2. The maximum density of each species found in each zone within a five by five meter plot. The unit is number of individuals per meter squared. For species marked with an asterisk, the unit is number of colonies per meter squared. STL = Sainte Luce; PTK = Petriky; MDN = Mandena.

Species	STL	PTK	MDN
Angraecum calceolus	0.28	2.28	0.36
Angraecum cf rhizomaniacum	0.08		
Angraecum crassum	0.12		
Angraecum eburneum var. superbum		0.60	
Angraecum eburneum var. xerophilum		5.24	
Angraecum filicornu	0.28		
Angraecum sesquipedale	0.20	1.72	
*Bulbophyllum cf cirrhoglossum**	0.48	1.00	0.20
*Bulbophyllum cf humblotii**	1.84		0.20
*Bulbophyllum cf multiflorum**	1.08		0.04
*Bulbophyllum cf vestitum var. meridionale**	0.60		
*Bulbophyllum elliotii**	0.48		
*Bulbophyllum longiflorum**			0.44
*Bulbophyllum sp1**	0.16		
*Bulbophyllum sp2**		0.32	
*Bulbophyllum sp3**		0.32	
*Bulbophyllum sp4**			0.16
*Cymbidiella falcigera**	0.04		0.04
Cymbidiella flabellata			2.40
Cynorkis elata	3.00		0.04
Cynorkis fastigiata	1.00		0.36
Disperis tripetaloides			0.76
Eulophia beravensis		10.24	
*Eulophia macra**		0.16	0.28
Eulophia sp1		0.04	
Eulophia sp2			2.12
Grammangis ellisii	0.04		
*Graphorkis concolor var. alphabetica**	0.08		0.04
Jumellea cf rigida	1.60		
Jumellea stenoglossa	1.20		
*Microcoelia aphylla**			0.04
Oeceoclades cf calcarata		1.20	
Oeceoclades cf spathulifera		0.04	

Appendix 2 continued.

Species	STL	PTK	MDN
Oeceoclades longibracteata		0.48	
Oeceoclades maculata		0.24	
*Oeceoclades pulchra**	0.04		0.12
Oeonia volucris	0.04		0.04
Oeoniella polystachys	0.12	0.92	1.76
Polystachya concreta	2.40		0.16
Vanilla planifolia	0.04		

Appendix 3. Epiphytic orchid species and their observed host tree species. STL = Sainte Luce; PTK = Petriky; MDN = Mandena.

Angraecum calceolus
STL: *Anthocleista sp, Diospyros sp, Faucherea sp, Intsia bijuga, Schizolaena sp*. PTK: *Asteropeia micraster, Bauhinia madagascariensis, Diospyros sp, Elaeodendron sp, Erythroxylon sp, Eugenia sp*. MDN: *Cynometra sp, Elaeodendron sp*.

Angraecum cf rhizomaniacum
STL: *Garcinia madagascariensis, Intsia bijuga*.

Angraecum crassum
STL: *Schizolaena sp*.

Angraecum eburneum var. superbum
PTK: *Diospyros sp, Eugenia sp*.

Angraecum filicornu
STL: *Leptolaena delphinensis, Sarcolaena multiflora, Uapaca sp*.

Angraecum sesquipedale
STL: *Intsia bijuga*, terrestrial. PTK: mostly terrestrial.

Bulbophyllum cf cirrhoglossum
STL: *Cuphocarpus aculeatus, Diospyros sp, Homalium involucratum, Intsia bijuga, Philippia sp, Sarcolaena multiflora*. PTK: *Campylospermum sp, Capurodendron delphinensis, Elaeodendron sp, Erythroxylon sp, Eugenia sp, Oplonia vincoides, Suregada sp, Tricalysia sp*. MDN: *Asteropeia micraster, Brexia sp, Brochoneura madagascariensis, Eugenia sp, Scolopia sp*.

Bulbophyllum cf humblotii
STL: *Diospyros sp, Homalium involucratum, Intsia bijuga, Polycardia phyllantoides, Sarcolaena multiflora, Uapaca sp*. MDN: *Poupartia minor.*

Bulbophyllum cf multiflorum
STL: *Bembicia uniflora, Cuphocarpus aculeatus, Diospyros sp, Eugenia sp, Intsia bijuga, Poupartia chapelieri, Sarcolaena multiflora, Uapaca sp*. MDN: *Brochoneura madagascariensis, Eugenia sp, Scolopia sp*.

Bulbophyllum cf vestitum var. meridionale
STL: *Sarcolaena multiflora*.

Bulbophyllum elliotii
STL: *Cuphocarpus aculeatus, Eugenia sp, Homalium involucratum, Intsia bijuga, Poupartia chapelieri, Uapaca sp*.

Bulbophyllum longiflorum
MDN: *Eugenia sp, Malleastrum sp*.

Bulbophyllum sp1
STL: *Dracaena reflexa, Uapaca sp*.

Appendix 3 continued.

Bulbophyllum sp2
PTK: *Campylospermum sp.*

Bulbophyllum sp3
PTK: *Intsia bijuga*.

Bulbophyllum sp4
MDN: *Eugenia sp*.

Cymbidiella falcigera
STL: *Beccariophoenix madagascariensis*. MDN: *Raphia farinifera*.

Grammangis ellisii
STL: *Homalium axillare, Morella spathulata*.

Graphorkis concolor var. alphabetica
STL: *Uapaca sp*. MDN: *Melaleuca quinquennervia*, terrestrial.

Jumellea cf rigida
STL: *Diospyros sp, Sarcolaena multiflora, Schizolaena sp*.

Jumellea stenoglossa
STL: *Diospyros sp, Intsia bijuga, Sarcolaena multiflora, Schizolaena sp*.

Microcoelia aphylla
MDN: *Eliaea articulata, Erythroxylon sp*.

Oeonia volucris
STL: *Saldinia littoralis*. MDN: *Onchostiamum sp*.

Oeoniella polystachys
STL: *Dombeya sp, Eugenia sp, Intsia bijuga, Sarcolaena multiflora*. PTK: *Asteropeia multiflora, Bauhinia madagascariensis, Elaeodendron sp, Eugenia sp*. MDN: *Cynometra sp, Eugenia sp, Intsia bijuga*.

Polystachya concreta
STL: *Intsia bijuga, Malleastrum sp, Pandanus sp, Sarcolaena multiflora*. MDN: *Phyllarthron illicifolium*.

Appendix 4. Phenology of orchid species found in this study during the season in which it was conducted (mid-April, 2012).

Species	**Vegetative**	**In Flower**	**In Fruit**
Angraecum calceolus	X		X
Angraecum cf rhizomaniacum		X	
Angraecum crassum	X		
Angraecum eburneum	X (*var. superbum*)	X (*var. xerophilum*)	
Angraecum filicornu	X	X	
Angraecum sesquipedale	X		
Bulbophyllum cf cirrhoglossum	X		X
Bulbophyllum cf humblotii	X	X	
Bulbophyllum cf multiflorum	X		X
Bulbophyllum cf vestitum var. meridionale	X		X
Bulbophyllum elliotii	X		X
Bulbophyllum longiflorum			X
Bulbophyllum sp1	X		X
Bulbophyllum sp2			X

Appendix 4 continued.

Species	Vegetative	In Flower	In Fruit
Bulbophyllum sp3			X
Bulbophyllum sp4			X
Cymbidiella falcigera	X		
Cymbidiella flabellata	X		
Cynorkis elata	X	X	
Cynorkis fastigiata		X	X
Disperis tripetaloides		X	X
Eulophia beravensis	X	X	
Eulophia macra	X	X	
Eulophia sp1	X		
Eulophia sp2	X		
Grammangis ellisii	X		X
Graphorkis concolor var. alphabetica	X		
Jumellea cf rigida	X		X
Jumellea stenoglossa	X	X	
Microcoelia aphylla	X		X
Oeceoclades cf calcarata			X
Oeceoclades cf spathulifera			X
Oeceoclades longibracteata	X		X
Oeceoclades maculata	X		
Oeceoclades pulchra	X	X	
Oeonia volucris		X	
Oeoniella polystachys	X		X
Polystachya concreta	X	X	X
Vanilla planifolia	X		